MEMORANDUM REPORT ARBRL-MR-03224

"MERF" THE BRL MOBILE EXPERIMENTAL RESEARCH FACILITY

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November 1982

US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
BALLISTIC RESEARCH LABORATORY
ABERDEEN PROVING GROUND, MARYLAND

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The development of a mobile instrumentation van for collecting and processing data at remote test firing sites has fulfilled a long time requirement of the Interior Ballistics Division of the Ballistic Research Laboratory. It has provided a quick response capability for making many accurate measurements on a number of gun test programs at remote locations. The van was equipped with the latest state-of-the-art instrumentation and enough flexibility was built into the design to accommodate most types of measurement programs.

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I. INTRODUCTION

For a number of years, there has been a requirement of the Mechanics & Structures Branch of the Interior Ballistics Division (IBD) of the Ballistic Research Laboratory (BRL) to make measurements on high priority gun test programs at various remote test sites. These sites include Picatinny Arsenal, Dover, NJ, Jefferson Proving Ground, IN; contractors facilities; and remote sites at the Aberdeen Proving Ground, MD.

Prior to the development of an instrumentation van, various electronic instruments required for a test program were gathered and shipped or hand carried piecemeal to a test site. A large amount of time was required to interconnect and check out these instruments because damage and malfunctioning equipment was a common result of the transportation process. In addition, the instruments were sometimes located in hostile environments which resulted in unsatisfactory measurements being made. This repeated shipping, assembly, and disassembly of equipment resulted in excessive wear and damage, long periods of instrument nonavailability, increased manpower requirements for tests, and general degradation of measured results.

During the fall of 1978, a van that was previously used as a mobile instrumentation facility, became available. It was decided to purchase this van and all necessary instrumentation to build a state-of-the-art data acquisition, recording, and processing facility. It was also decided to call this van the Mobile Experimental Research Facility (MERF) with the following conceptual objectives:

- To provide state-of-the-art analog and digital data acquisition and processing instrumentation.
- To provide maximum system configuration flexibility to be able to accommodate most types of gun measurement programs.
- To provide on-site analog-to-digital conversion and digital data processing including plotting and presentation.
- To provide a storage medium and software interface for other IBD systems.
- To provide quick response and complete system mobility for making accurate measurements at remote sites.

II. DESCRIPTION OF THE MERF VEHICLE

The MERF van is a 27 foot Dodge TRAVCO motor home type of vehicle that is 8 feet wide and completely housed in a fiberglass body shell. The forward 5 feet of the vehicle contains the driver and passenger compartment with the engine centered below this section. The useable space for instrumentation is 17 feet long by 7 feet wide with a height of 76 inches. The rear 5 feet of the vehicle contains a table and bench type seating compartment. The vehicle is powered by a Chrysler 413 cubic inch engine, and in conjunction with a 70 gallon gasoline tank, the cruising range is approximately 500 miles. The total vehicle road weight is 14,000 pounds. Ancillary equipment contained in the van consists of two 6 KVA electrical power generators, two 12,000 BTU/Hr

air conditioners, eight 28-inch electrical baseboard heaters, a combination stove-sink-refrigerator (with its associated water pump, supply tank and holding tank for waste water), twelve dual 12-volt ceiling mounted lamp fixtures, an AC to DC inverter for battery charging, and an outside roof-mounted luggage pod and rack. The electrical system for the van is configured so that all equipment can be operated from the two electrical power generators or from an external power pole through a 100-foot cable. The equipment in the van is separated into two electrical systems, electronic instruments and housekeeping (i.e., air conditioners, heaters, lights, etc.), so that each system can operate independently from the two generators or power poles. This was done to eliminate interference and power line surges on the electronic instrumentation. The two electrical power generators are driven by gasoline engines which are fed from the main gasoline tank.

A photograph of the "MERF" van is shown in Figure 1.

III. DESCRIPTION OF THE INSTRUMENTATION CAPABILITIES

A. General Instrumentation Description

The latest state-of-the-art electronic instrumentation was purchased and used to equip the van. Most of the instruments are mounted in five standard 6-foot instrumentation racks as shown in Figure 2. These racks are bolted together and bolted through the floor to the vehicle frame to insure stability while the van is on the road. A removable safety bar is used to anchor the top of the racks to the rear frame of the vehicle while traveling.

The instruments are grouped together in the racks according to their function. As seen in Figure 3, Rack No. 1 contains all of the digital storage instruments plus test instruments; Rack No. 2 contains the analog tape recorder plus the multiplexing system for expanded recording capabilities; Rack No. 3 contains the ancillary instruments for monitoring, controlling, timing, and patching; and Rack No's. 4 and 5 contain all of the prerecording signal conditioning instruments. A desktop computer is mounted on a work table attached to the left side of the five racks. A sixth rack with drawers, attached to the left of the computer table, is used for the storage of manuals, supplies, and small parts. The photograph in Figure 4 shows the desktop computer and table top.

B. Instrumentation Functions

1. Signal Conditioning. The primary purpose of signal conditioning instruments is to transform the output of a transducer or a sensing function such as charge, resistance change, switch closure, or voltage to a form that is suitable for recording. In the MERF van, primary recording is performed directly by a magnetic tape recorder or indirectly through a multiplexing system. The standard tape input requires a signal with an amplitude of 1.0 volts RMS or ± 1.414 volts peak-to-peak.

2. Types of Signal Conditioning

a. Charge Amplifers - convert the charge output of a transducer to an amplified voltage that can be recorded directly. Also, provide some filtering of the signal.

Figure 1. The BRL Mobile Experimental Research Facility Van

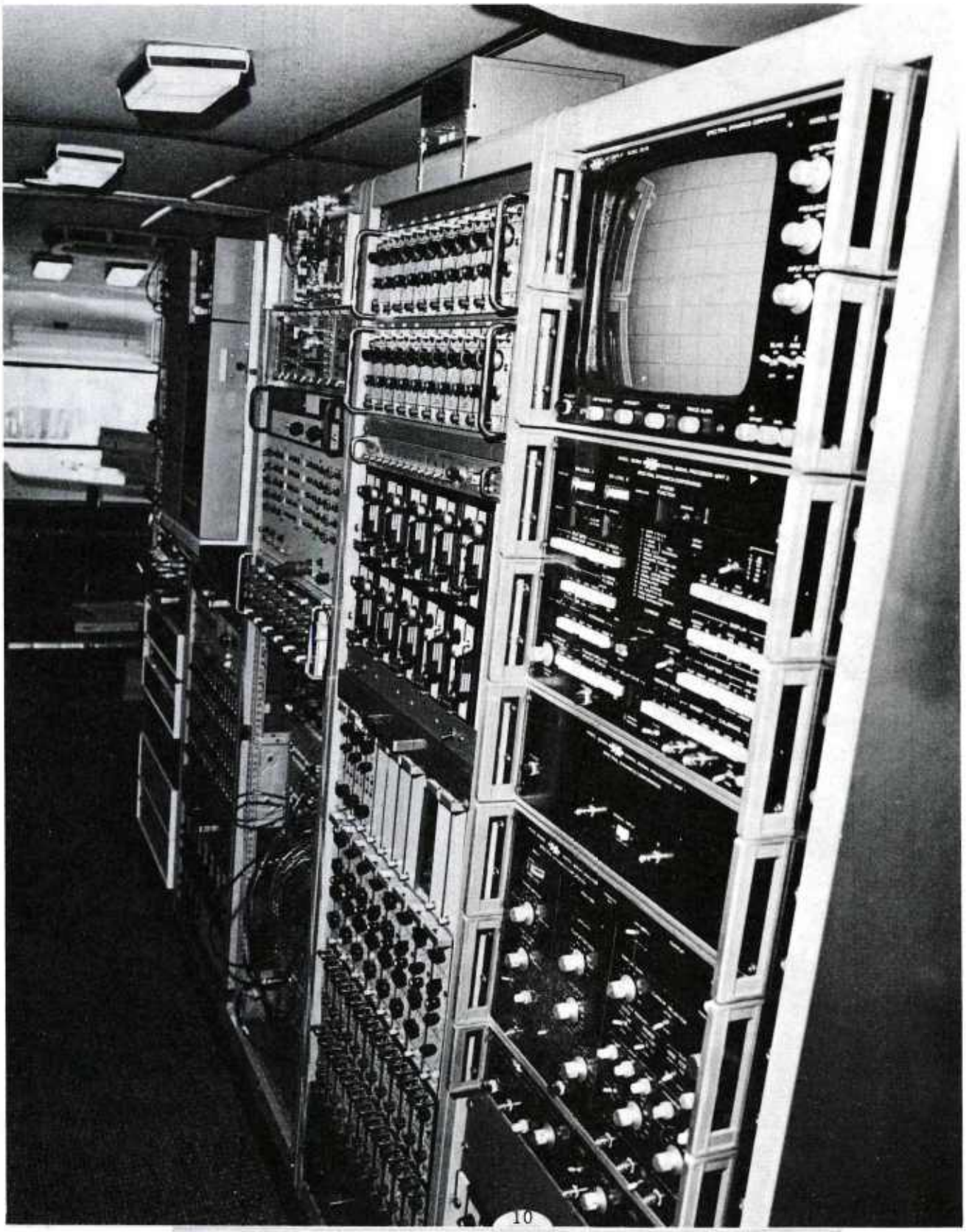

Figure 2. Electronic Instrumentation Mounted in the "MERF" Van

MERF INSTRUMENTATION RACK LAYOUT

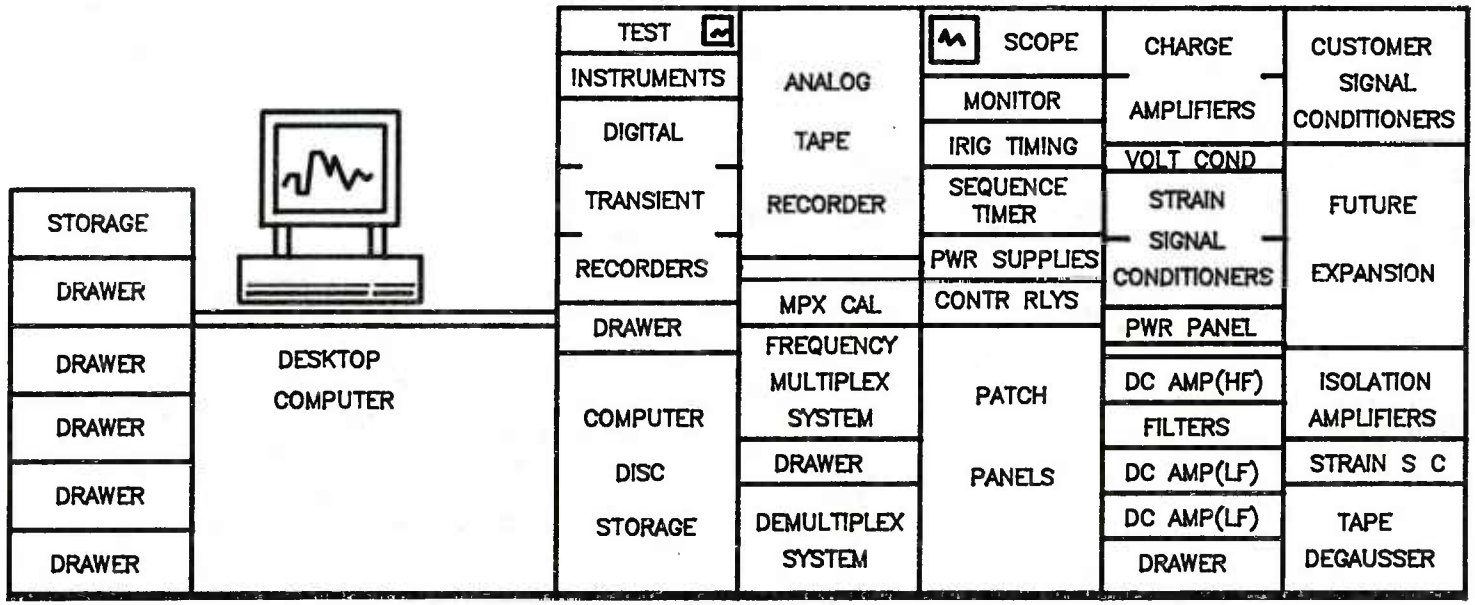

Figure 3. MERF Instrumentation Rack Layout

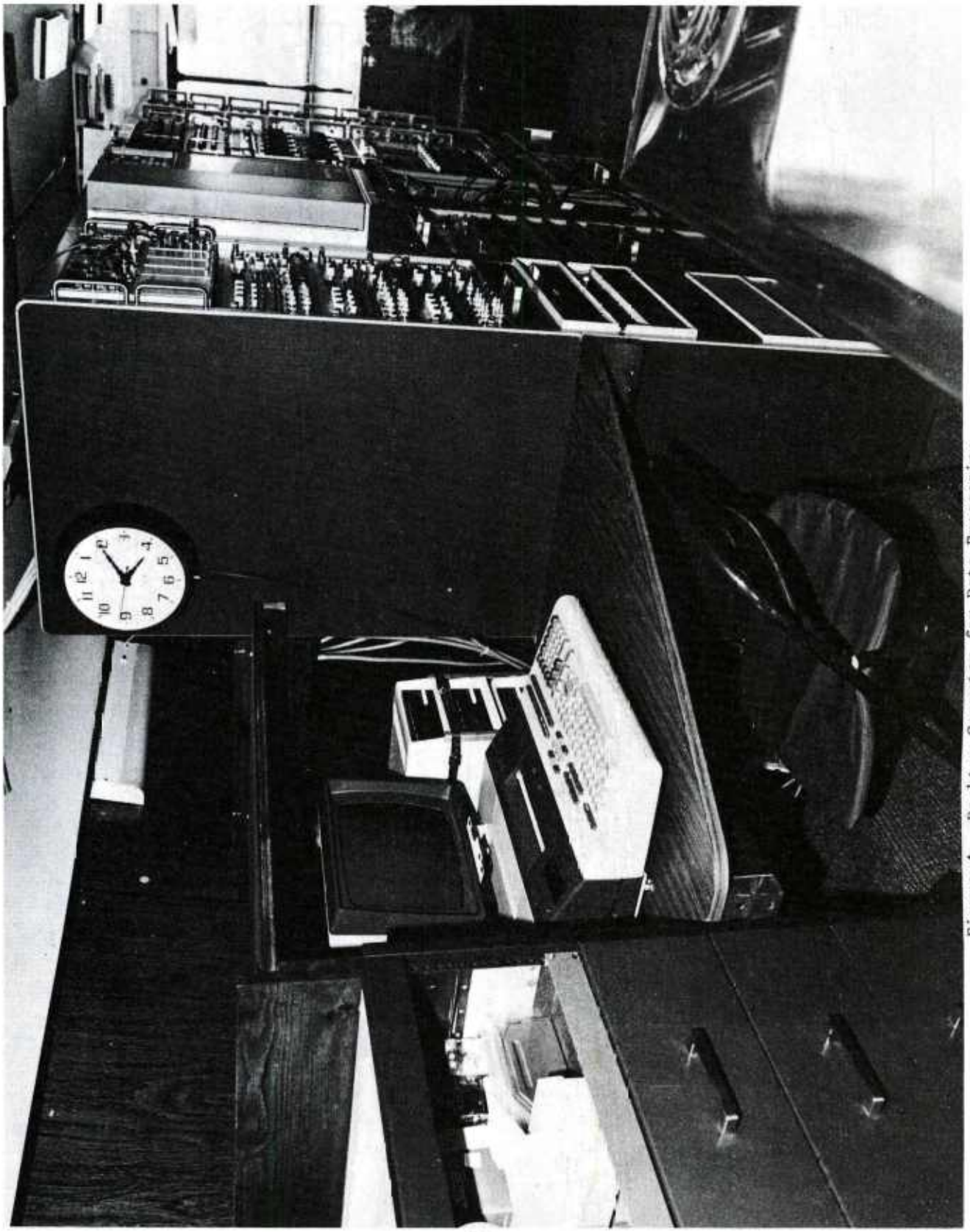

Figure 4. Desktop Computer for Data Processing

b. Resistance Signal Conditioners - provide a stable voltage or current excitation source plus completion resistors when used in a bridge or ratio configuration. Provide voltage amplification with a low impedance output for direct recording.

c. Piezotron or Voltage Mode Conditioners - provide a constant current source and output coupling capacitor for a series of piezo type transducers with internal impedance converters. A voltage output through the coupling capacitor is provided which may be adequate for direct recording or require some amplification.

d. Direct Coupled (DC) Amplifiers - provide general purpose voltage amplification with gain ranges that are continuously variable from 1 to 2500. There are 24 units with a bandwidth from DC to 100 kilohertz (kHz) and 4 units with a bandwidth from DC to 2 megahertz (MHz). The amplifier inputs are configured on the patch panel to accept either differential or single ended output signals. Single ended signals can be fed to the amplifiers in either a noninverting or inverting mode. With no signal patched into the amplifier, the input is connected to ground. There are also 12 amplifiers, with a DC to 100 kHz bandwidth, that are used for external signal isolation. External signals from another facility, or source outside the van, are fed into the differential inputs at these units and isolated from ground. This eliminates unwanted ground loops and 60 Hz interference.

e. Filters - Eight general purpose filters are provided in the van. The filters have low pass, high pass, band pass, and band reject modes with linear phase and constant amplitude characteristics. Frequency response is variable between 10 Hz and 1 MHz.

3. Monitoring and Recording

a. Monitoring - Rack No. 3 contains the primary large screen monitor oscilloscope and a companion auxiliary chassis that contains the monitoring circuits plus other ancillary circuits which will be described in a later section. The monitor circuits consist of an integrated circuit type of instrumentation amplifier for each input channel to the tape recorder. Each signal is fed through the noninverting amplifier input, and the inverting input is used to offset the signal in a positive or negative direction, if desired. An example of the use of this offset is for recording pressure pulses where all signals deflect in one direction only. Since the tape input requires a 1.0 volt RMS, or ± 1.414 volts peak-to-peak, an offset of -1.4 volts is used allowing a peak pressure signal deflection of + 2.8 volts, thereby using the full input bandwidth capability of the tape recorder. In addition, a common fiducial pulse is fed to all tape channels simultaneously through the inverting input of these amplifiers. All amplifiers have a frequency response from DC to 300 kHz.

b. Recording - All recording in the van is accomplished with a Honeywell Model 101 Tape Recorder. This recorder has a 14 channel record and reproduce capability using 1 inch wide magnetic tape. The primary electronics used are the Inter-Range Instrumentation Group(IRIG) Wideband I electronics providing a frequency response from DC to 80 kHz with maximum available signal-to-noise ratio. Where required, IRIG Wideband II electronics are used giving a frequency response from DC to 500 kHz, but with reduced signal-to-

noise ratio. In addition, direct recording electronics are available providing a frequency response from 300 Hz to 2 MHz.

A number of firing test programs required many channels of data to be recorded, more than the 14 channels available on the tape recorder. To accommodate this requirement, a frequency multiplex (MPX) system was installed in the van. This system added 48 channels for indirect data recording and only required six tape recorder channels. This fact left eight tape channels for direct recording. The MPX record system requires the use of direct electronics on the tape recorder since frequencies between 128 kHz and 800 kHz are recorded. A compromise has to be made when using the MPX system due to the fact that the data bandwidth is reduced to a range of DC to 8 kHz and there is a slight possibility of some cross talk between data channels.

The MPX system requires six sets of electronics (each set consists of eight subcarrier oscillators plus a mixing amplifier and reference frequency) to record 48 data signals on the six tape channels. When the data are reproduced, only one set of electronics, including eight data discriminators and a reference discriminator, is required because the same eight subcarrier frequencies are recorded on each tape channel. Normally, data are recorded at a tape speed of 120 inches per second (ips) and reproduced at a speed of 7.5 ips, thereby giving a time expansion of the data for reduction purposes. One disadvantage of the MPX system is that only one tape channel can be reduced at a time.

A block diagram of the MPX system utilizing one tape recorder channel is shown in Figure 5.

4. Digital Data Systems. After the data have been recorded on the analog magnetic tape recorder, it can be processed by the digital data system for quick-look plots, or, with a little more time, report quality plots with engineering units. The Digital Data System consists of three, four-channel Biomation digital storage recorders and a desktop computer including disc drive and flatbed plotter peripherals.

a. Biomation Recorder - Three Biomation recorders are used in the van's digital data system as shown in Figure 3. The data recorded on analog magnetic tape are reproduced at a reduced speed and fed to the Biomation recorders. These recorders start storing data, digitally, when an external trigger pulse is received or triggering is obtained from the start of one of the input signals. Each recorder has the ability of storing data in a one, two or four-channel mode. The total memory contained in each recorder is 4096 words and all of the memory is used for the one-channel mode. The two-channel mode has 2048 words of memory for each channel, and the four-channel mode has 1024 words of memory for each channel. Each word in memory has a resolution of 10 digital bits producing an accuracy of 0.1 %.

b. Desktop Computer - The desktop computer is inter-connected with the three Biomation recorders, disc drive and flat bed plotter and is used to process and present all data in plotted form. Data are transferred from the Biomation memory to the computer memory, then processed and stored on a disc. The disc drive contains two separate discs, one an internally fixed disc used for storing the data reduction programs and a removable cartridge-type disc that is used for storing all data. The fixed disc contains a

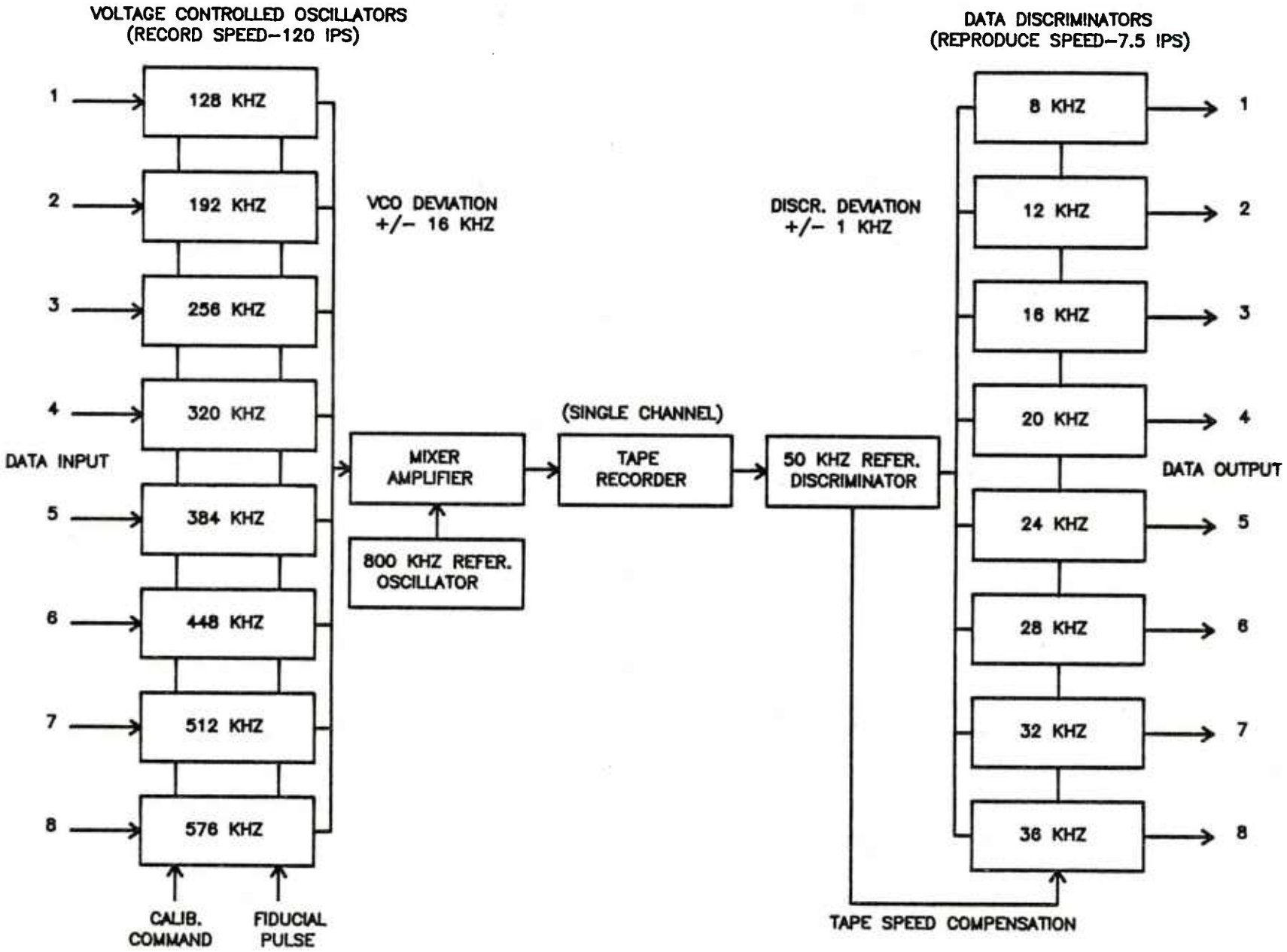

Figure 5. Tape Recording Multiplex System

complete data reduction package[1], including baseline level correction, conversion of units, etc., plus programs for spectral analysis, digital filtering, integration, and differentiation. Final plots are presented on an internal computer printer or the flatbed plotter.

5. Ancillary Systems

a. Patch Panels

During the design process of the van, it was decided to configure the van with a plug-in type of patch-panel system to provide the maximum amount of flexibility on various types of gun test programs. Where applicable, each input and output connector, on all of the instruments contained in the racks, is connected to a patch-panel jack. In addition, a series of patch jacks is connected to an access panel that is available through a door on the outside of the van. This system enables a unique arrangement of instrument hookups for each test program, as well as allowing for the insertion of amplifiers or filters in the signal paths or the quick change of any test arrangement. It also provides a quick access for monitoring or testing the instruments. A typical test arrangement for chamber pressure using the patch system is shown in Figure 6.

b. Sequence Timers

Two sequence timers are used in the van for controlling or timing various functions during a firing program. The main timer has nine timed stages that control nine double-pole, double-throw(DPDT) power relays. Each stage can be set for a time period from 1.0 millisecond to 9999.0 milliseconds in 1.0 millisecond increments. These stages are primarily used for momentarily shorting the input to charge amplifiers, transferring all MPX inputs to a fiducial line, starting an auxiliary sequence timer, or any event required for a test program. The auxiliary sequence timer is used for putting calibration steps on all signal conditioners or directly on the tape recorder. These calibrations consist of a baseline plus five equally spaced steps and return to baseline with each step having a duration of 50 milliseconds. The output of this timer is either a voltage level or a relay closure. This timer also generates a 5-millisecond fiducial pulse that is recorded on every tape channel for use as a common time reference. An example of a calibration, fiducial pulse, and event are shown in Figure 7.

c. Time Code Generator

The Time Code Generator in the van is actually a precision generator and reader. It has the provision for generating both the IRIG "A" and "B" modulated time codes for recording on tape. The coded output provides hours, minutes, and seconds, plus a three-digit identification (ID) number. This ID number, like e.g. the Julian date, is used for numbering each segment of the

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[1] *J.N. Walbert, "Interactive Data Acquisition, Analysis, and Presentation Software for Experimental Research Facilities in the Interior Ballistic Division at BRL," to be published.*

TYPICAL TEST ARRANGEMENT FOR CHAMBER PRESSURE

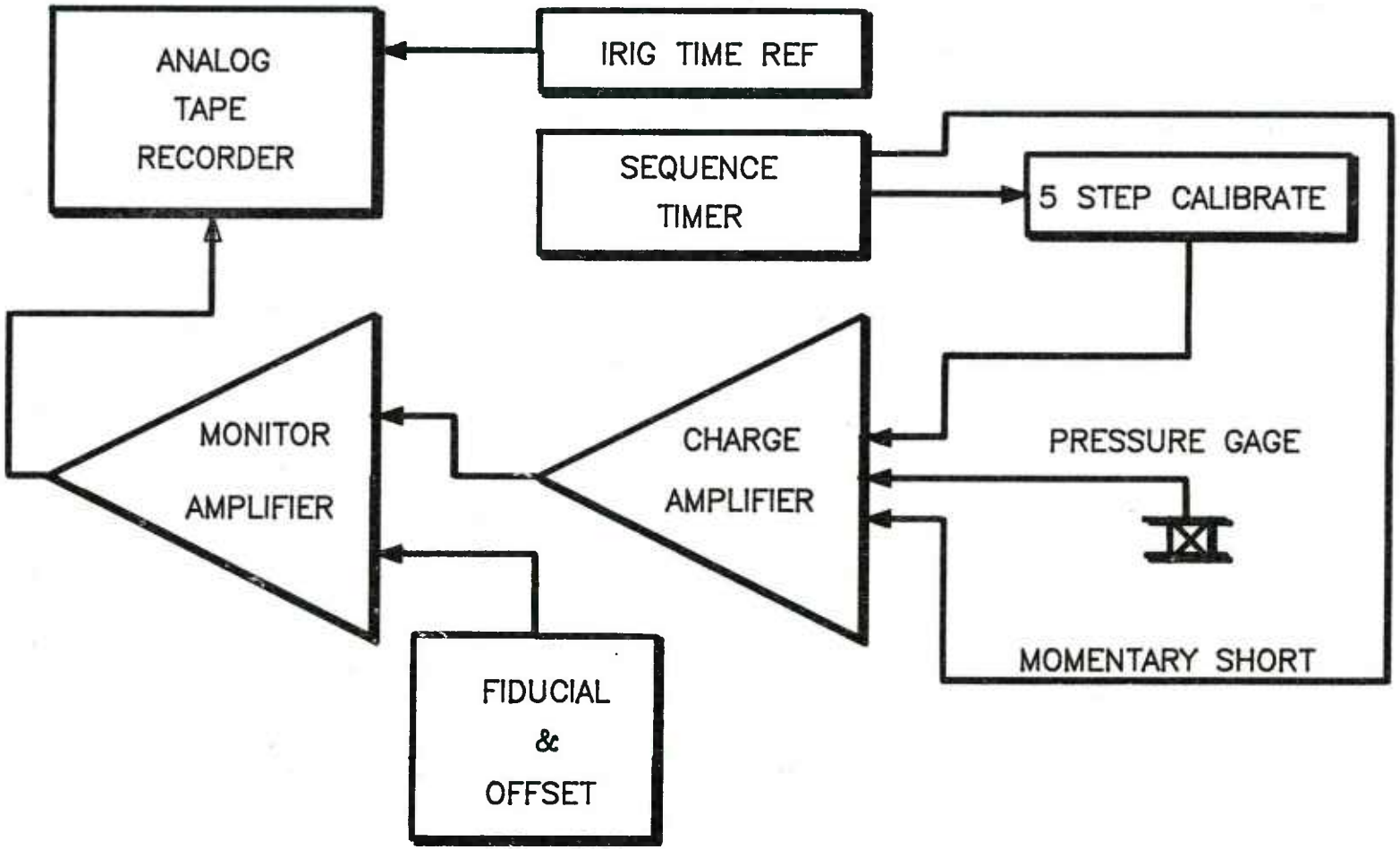

Figure 6. Typical Test Arrangement for Chamber Pressure

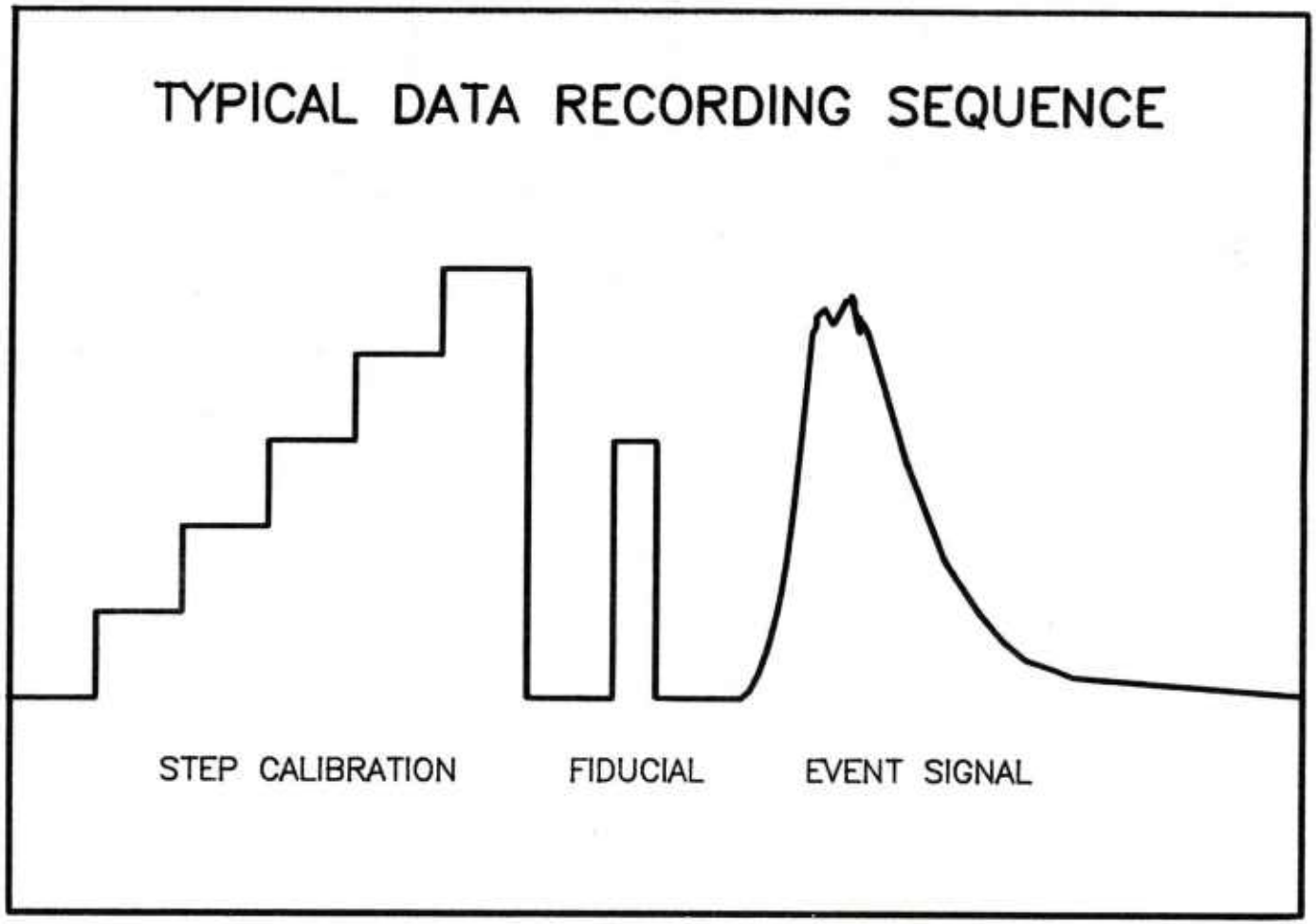

Figure 7. Typical Data Recording Sequence

magnetic tape that contains a record, calibration, etc., and it is manually sequenced from the front panel of the instrument. The reader portion of the instrument is used when reproducing tape records so that each segment of tape can be identified by the ID number, and the time of the day can also be identified. This reader will read the time code when reproducing tape either in the forward or reverse direction. The modulated frequency can also be used for a reference.

d. Test Instruments

Rack No's. 1 and 3 contain modular test instruments which can be used in the adapters contained in these racks or a portable three-section case. This portable case permits the operation of any three instruments at a test site remote from the van (i.e., gun mount, doppler radar setup, etc.). The available instruments are a two-channel oscilloscope, function generator, pulse generator, digital multimeter and thermometer, digital counter and six, triple-output power supplies. When mounted in the rack adapters, the power supplies are primarily used for calibration voltages or resistance bridge sources. The other test instruments have either their outputs or inputs connected to patch-panel jacks for monitoring purposes.

IV. SUMMARY

The "MERF" van has been operational for more than two years and has provided an efficient, environmentally controlled facility for obtaining large amounts of accurately measured data, plus the economical transportation of instrumentation and operators to a test site. The use of the van at these sites has provided a number of advantages over previous methods of shipping and hand carrying instruments. These are:

- The time involved for uncrating, assembling, and interconnecting the instruments has been eliminated.
- Necessary repairs to damaged instruments, caused by the shipping process, has been minimized.
- Upon arrival at a test site, the instruments can be positioned immediately and set up quickly, usually in 2-4 hours depending upon the complexity of the test.
- After a test, the van and cables can be wrapped up in approximately one hour and be on the road.
- The number of personnel required for a test has been reduced. Normally only 2 people are required to drive the van to a test site, set up, and operate the instrumentation.
- The van has made it possible to carry more than the minimum required instruments for a test and also provides familiar work surroundings for the operators.

A listing of the MERF field test programs conducted for the first two years of operation is shown in Table 1. In addition to the field test programs, the facility is used for data reduction while parked outside the laboratory at BRL.

TABLE 1. MERF FIELD TEST PROGRAMS

	DATE	TEST SITE	TEST DESCRIPTION	MEASUREMENTS	GUN SYSTEM	ROUNDS
1)	25 May- 1 June '80	Jefferson Proving Ground, IND.	M-735 Pressure	7 Pressure Gages	M-68	31
2)	20-22 Nov '80	BRL TRANSO. Range, APG	RFO Velocimeter	Muzzle Velocity	75 MM HSTVL	12
3)	26 Feb- 3 Mar '81	GE Test Range Burlington,VT	Tube Motion Verification	10 Accelerometers 20 Strain Gages 4 Proximity Gages 2 Optrons	30 MM Special Mod GAU 8	7
4)	14-18 Apr '81	Picatinny Ars. Dover, NJ	Maxwell Collar	8 Accelerometers	M-68	6
5)	19-25 Jul '81	ARES, Port Clinton, OH	Muzzle Motion	8 Accelerometers 9 Strain Gages Doppler Radar	75 MM HSTVL 90 MM HSTVL	13 6
6)	4-9 Oct '81	Jefferson Proving Ground, IND.	Maxwell Collar	6 Accelerometers	M68	20
7)	1-13 Nov '81	GE Test Range Burlington, VT	Tube Motion Verification	6 Accelerometers 20 Strain Gages 12 Proximity Gages 1 Pressure Gage 2 Optrons	30 MM Special Mod GAU 8	9
8)	18-20 Nov '81	BRL TRANSO. Range, APG	Muzzle Motion	4 Strain Gages	75 MM HSTVL	22
9)	Dec' 81- May '82	MTD Test Range, APG	M-735 Pressure	3 Pressure Gages	M-68	56

APPENDIX A

DATA CHANNEL CAPACITIES

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DATA CHANNEL CAPACITIES

1.	Tape Recorder	14 Channels 1 Voice
2.	Frequency Multiplex (Requires 1 Tape Channel for 8 MPX Channels)	48 Channels
3.	Charge Amplifiers	20 Channels
4.	Resistance Signal Conditioners	15 Channels
5.	Voltage Mode Conditioners	12 Channels
6.	Direct Coupled Amplifiers	
	100 kHz Bandwidth	24 Channels
	2 MHz Bandwidth	4 Channels
	100 kHz Bandwidth Isolation	12 Channels
7.	Filters (Multi-Mode)	8 Channels
8.	Sequence Timer (DPDT Contacts)	9 Stages
9.	Biomation Recorders	12 Channels

The channel capacity for the Frequency Multiplex, Charge Amplifiers and Direct Coupled Amplifiers can be expanded by adding available equipment to the van.

APPENDIX B

GENERAL SPECIFICATIONS FOR THE MERF VAN INSTRUMENTS

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GENERAL SPECIFICATIONS FOR THE MERF VAN INSTRUMENTS

General specifications for the MERF Van Instruments.

1. Tape Recorder, Honeywell Model 101

   - Number of Channels - 14 on 1 inch tape
   - Number of Speeds - 7 from 1.87 to 120 IPS
   - Frequency Response
     -FM(WBI), DC to 80 kHz, 45 db SNR
     -FM(WBII), DC to 500 kHz, 34 db SNR
     -Direct, 0.4 to 2000 kHz, 26 db SNR
   - Record and reproduce in forward and reverse direction
   - Automatic channel calibration and check out

2. Multiplex System, EMR Model 4530

   - Number of Channels - 48, 8 per tape channel
   - Center Frequencies - 8, from 128 kHz to 576 kHz in 64 kHz steps
   - Input Range - 1 to 10 volts peak-to-peak, 100k-ohms impedance
   - Frequency Deviation - ± 16 kHz
   - Input Data Response - DC to 8 kHz

3. De-Multiplex System, EMR Model 4130

   - Number of Channels - 8
   - Center Frequencies - 8, from 8 kHz to 36 kHz in 4 kHz steps
   - Input Range - 2 millivolts to 5 volts RMS
   - Frequency Deviation - ± 1 kHz
   - Output Range - ± 0.1 to ± 10 volts @ ± 100 milliamperes
   - Data Response - DC to 500 Hz.

4. Charge Amplifiers, PCB Model 462A

   - Input Range - 5 to 1 x 10^6 picocoulombs
   - Output Range - ± 0.1 to ± 10 volts, 100 ohms impedance
   - Output Filter - 10 kHz or 50 kHz, low pass

- Number of Channels - 20 (Expandable)

5. Voltage Mode Conditioner, PCB Model 483A

   - Number of Channels - 12
   - Excitation Current - 2 to 20 milliamperes per channel
   - Voltage Gain - 1
   - Coupling Capacitors - 10 microfarad

6. Amplifier, Direct Coupled, Ectron Model 751EM

   - Input Range - 0 to ±10 volts, 20 megohms impedance
   - Gain - 1 to 2500, variable
   - Output - ±10 volts DC @ ±100 milliamperes
   - Frequency Response (3db) - DC to 100 kHz
   - Filter - 1-, 10-, 100-, 1k-, 10k-, and 100k- Hz low pass
   - Number of Channels - 36

7. Amplifier, Direct Coupled, Dynamics Model 7525 EMRR

   - Input Range - 0 to ±10 volts, 10 megohms impedance
   - Gain - 1 to 2500 variable
   - Output - ±10 volts DC @ ±100 milliamperes
   - Frequency Response (3db) - DC to 2 MHz
   - Filter - 1-, 10-, 100-, 1k-, 10k-, and 100k- Hz Low Pass
   - Number of Channels - 4

8. Filter, Dynamics Model 6364 A/KQ

   - Input Range - 0 to ± 10 Volts, 10 megohms impedance
   - Gain - 1
   - Output - ± 10 Volts @ ± 100 milliamperes
   - Frequency Response
     10 Hz to 100 kHz low pass, linear phase or Butterworth response
     100 Hz to 1 MHz high pass
     100 Hz to 100 kHz band pass or band reject

9. Resistance Signal Conditioner, Endevco Model 4470

- Input - 1,2, or 4 active resistive elements
- Output - 1 to 30 volts DC @ 100 milliamperes
- Calibration - Internal resistors and relays for remote or front panel operation
- Number of Channels - 15

10. Time Code Generator/Reader, Systron-Donner Model 8152

- Generator Output - IRIG "A" Modulated Carrier (10 kHz) or IRIG "B" Modulated Carrier (1 kHz)
- Output Amplitude 0 to 10 volts peak-to-peak @ 15 milliamperes
- Output Code - Hours, minutes, seconds and either days or identification number
- Reader Input Frequency Range - 30 Hz to 500 kHz
- Reader Input Voltage Range - 50 millivolts to 50 volts peak-to-peak
- Reader Input Impedance - 100k ohms

11. Sequence Timer, Special Systems Model SSC0021

- Number of Stages - 10 (Dual)
- Settable Times - 0 to 9999 milliseconds
- Time Resolution - 1 millisecond
- Output - Mercury wetted relay contacts rated for 5 amperes at 250 voltamperes
- Special Features - Auto reset on 10th stage, manual operation, override switch, and auto timing or off.

12. Digital Recorder, Biomation Model 1015

- Number of Units - 3
- Number of channels per unit - 1,2, or 4
- Input Range - 100 millivolts to 50 volts full scale AC or DC at 1.0 megohm input impedance
- Offset Range - ± Full scale
- Total Memory - 4096 words with 10 bit resolution per word

- Sample Rate - 0.01 to 10 kHz, settable in a 1-2-5 sequence
- Input Bandwidth - DC to 25 kHz
- Record Modes - Normal, Delayed Trigger and Pre-Triggering
- Trigger Delay - 10 to 9990 Samples
- Output - Ten bit parallel TTL levels

13. Monitor and Test Instruments

- Oscilloscope, Tektronix Model R5110
- Oscilloscope, Tektronix Model SC-502
- Function Generator, Tektronix Model FG-502
- Digital Multimeter, Tektronix Model DM-501
- Digital Counter, Tektronix Model DC-503
- Pulse Generator, Tektronix Model PG-501

14. Computer and Peripherals

- Computer, Hewlett Packard Model 9845B
- Disc Drive, Hewlett Packard Model 7906MR
- Plotter, Hewlett Packard Model 9872B

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